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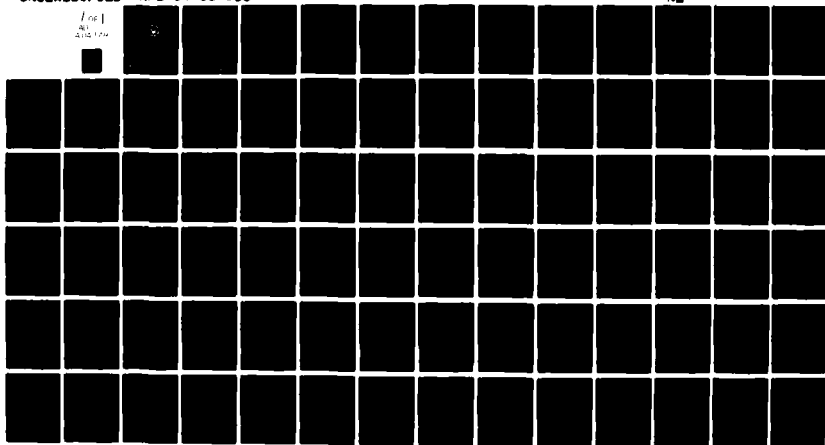
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THESIS

An Approach to the Application of Life Cycle Cost
Concept in Weapon Systems Acquisition for the
Venezuelan Navy

by

Jose G. Gil Rojas

December 1981

Thesis Advisor:

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Prepared for:
Naval Postgraduate School
Monterey, Ca. 93940

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REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM	
1. REPORT NUMBER NPS-54-81-013	2. GOVT ACCESSION NO. AD-A244 479	3. RECIPIENT'S CATALOG NUMBER	
4. TITLE (and Subtitle) An Approach to the Application of Life Cycle Cost Concept in Weapon Systems Acquisition for the Venezuelan Navy		5. TYPE OF REPORT & PERIOD COVERED Master's Thesis December 1981	6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s) Jose G. Gil Rojas		8. CONTRACT OR GRANT NUMBER(s)	
9. PERFORMING ORGANIZATION NAME AND ADDRESS Naval Postgraduate School Monterey, California 93940		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS	
11. CONTROLLING OFFICE NAME AND ADDRESS Naval Postgraduate School Monterey, California 93940		12. REPORT DATE December 1981	13. NUMBER OF PAGES 82
14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office)		15. SECURITY CLASS. (of this report) Unclassified	
15a. DECLASSIFICATION/DOWNGRADING SCHEDULE			
16. DISTRIBUTION STATEMENT (of this Report) Approved for public release; distribution unlimited			
17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)			
18. SUPPLEMENTARY NOTES			
19. KEY WORDS (Continue on reverse side if necessary and identify by block number) Life Cycle Cost, Ships, Operating and Support Costs, Life Cycle Costs of Weapon Systems, Acquisition.			
20. ABSTRACT (Continue on reverse side if necessary and identify by block number) This thesis presents a review of the Life Cycle Cost (LCC) concept as it is applied in weapon systems acquisition. A methodology is devel- oped for preparing estimates of the Support Investment (SI) and Operating and Support (O&S) costs of ship's acquisition programs. The use of cost models in LCC procurement is analyzed. Also, a methodology for implemen- tation of Life Cycle Cost procurement within the Venezuelan Navy is presented. The study constitutes an attempt to introduce the Life Cycle			

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An Approach to the Application of Life Cycle Cost
Concept in Weapon Systems Acquisition for the
Venezuelan Navy

by

Jose G. Gil Rojas
Commander, Venezuelan Navy

Submitted in partial fulfillment of the
requirements for the degree of

MASTER OF SCIENCE IN MANAGEMENT

from the

NAVAL POSTGRADUATE SCHOOL
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ABSTRACT

This thesis presents a review of the Life Cycle Cost (LCC) concept as it is applied in weapon systems acquisition. A methodology is developed for preparing estimates of the Support Investment (SI) and Operating and Support (O&S) costs of ship's acquisition programs. The use of cost models in LCC procurements is analyzed. Also, a methodology for implementation of Life Cycle Cost procurement within the Venezuelan Navy is presented. The study constitutes an attempt to introduce the Life Cycle Cost concept within the Venezuelan Navy, therefore the author has avoided indulgence into detailed subsystems, and has concentrated on the working and interrelationships within an entire system.

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I. INTRODUCTION

A. NATURE OF THE PROBLEM

The new weapon systems entering the defense inventory bring with them a degree of complexity and sophistication never equalled before. These achievements are being attained in an environment which is characterized by spiraling inflation and scarcity of resources. The associated penalties are evidenced by higher initial acquisition costs, and ever-increasing complexity of the acquisition process.

While there is much concern about the rising costs of acquisition, it is becoming apparent that these initial costs may not be the most significant factor when considering the operating and support costs associated with the useful life period of equipment. By including the cost of systems operation and support, the total system cost can be determined to a much better degree with a more sound basis for decisionmaking.

Increased emphasis has been placed on cost-effectiveness analysis in an effort to procure the most effective and efficient hardware available. Such efforts entail analysis of complex interrelationships among man, machine, and organization. Conceptually, one-half of the cost-effectiveness analysis consists of arriving at a Life Cycle Cost (LCC) for a proposed system.

Life Cycle Cost plays the following role in defense management. During a system's definition phase, LCC estimates are parametric cost equations used to estimate the system's ultimate cost. During the system's development phase, LCC estimates are used to identify the

minimum cost of the system. LCC attempts to describe all costs of acquisition and ownership incurred over a specific period of time, typically 10 years. Considering the pressing military budget constraints, and the need for the Venezuelan Armed Forces to have sufficient weapons to meet national security requirements, the Navy must pursue a program designed to reduce both the initial cost of system acquisitions as well as ownership costs.

Historically, the procurement of weapon systems within the Venezuelan Navy has been made using the traditional approach of trade-off between system effectiveness and minimum procurement cost, with little or no consideration being given to operating and support costs that will be encountered when the system is included in the inventory.

In 1977, the Venezuelan Navy established a program to replace part of the old fleet of destroyers with "LUP0" class frigates to be acquired from Italy. Under this program, six modern ships were promised for delivery between 1979 and 1982. As a consequence of this program, in 1979 the Navy implemented Integrated Logistic Support, a system engineering process whose main effort was to be directed toward solving operating and support problems which might originate after the ships were delivered, and throughout their operational life. The implementation of the Integrated Logistic Support System constitutes the first step taken by the Navy in formulating the concept of LCC. Unfortunately, this first attempt reflects a lack of compatibility and coordination between the acquisition policy and the philosophy of Integrated Logistic Support.

During the acquisition stage if no consideration is given to operating and support cost, the Navy will be confronted with unbudgeted future operating and support costs incurred by the new systems. If this pattern is allowed to continue, the bulk of the annual Navy budget will become allocated to support existing systems, thereby reducing or perhaps delaying for a long time, future acquisition programs.

B. PURPOSE OF THIS THESIS

The purpose of this thesis is to introduce the LCC concept within the Venezuelan Navy through the development of a methodology for their specific application. Venezuela acquires most of its weapon systems from other countries where such systems already have been developed, produced, tested, and deployed. For this reason, the methodology developed here is devoted to the system Support Investment (SI), and Operating and Support (O&S) costs processes of the weapon system's acquisition.

Venezuela currently needs a broad understanding of LCC. For this reason, the author has avoided indulgence into detailed subsystems, and has concentrated on the working and interrelationships within an entire system.

II. LIFE CYCLE COST

A. THE CONCEPT OF LIFE CYCLE COST

One of the most important weapon system acquisition concepts to emerge in recent years is that of LCC. The introduction of life cycle cost thinking has been the result of planner's recognition of the need to consider all significant costs associated with the decision to buy one firm's product instead of another's.

LCC forecasts and schedules costs other than the original purchase price. Other costs are incurred during the use of the item which has been procured. For example: In addition to the initial cost of a motor, additional costs will be incurred during its operational life, i.e., fuel costs, operating costs, labor costs, training costs, maintenance costs, etc. Life cycle costing attempts to account for these additional cost factors, along with the original purchase price, in arriving at an overall cost of ownership of a given device or system.

The life cycle of an item begins with the first feasibility study for its production and/or use, including development, production, and utilization phases, and ends with the disposal of the item. However, consideration of all life cycle phases, and their effect on the cost of ownership, should be included in any purchase decision.

The LCC of an item, therefore, is the total cost incurred in research, development, production, operation, and the final disposal of an item. The total cost of ownership is that portion of the LCC which is incurred by a using agency or organization. Note, however, that research and development costs usually are included in the selling price, and the user indirectly absorbs some portion of those costs.

According to the U.S. Department of Defense:

"Life Cycle Cost means the sum of direct, indirect, recurring nonrecurring, and other related costs incurred, or estimated to be incurred, in the design, development, production, operation, maintenance, and support of a system over its anticipated useful span." [Ref. 1]

Another way of looking at life cycle cost is given by William H. Boden, program director of the Magnavox Company:

"Life cycle cost is the total cost of acquiring the product, establishing the necessary logistical base from which to deploy and use the product, and maintain the product in operable condition over some prescribed period of time." [Ref. 2]

In the context of this paper, life cycle costs are to be understood as the total cost to the Venezuelan Government for the acquisition and ownership of a particular system. Life cycle costing, therefore, is the technique by which analytical study of a system's LCC is accomplished, taking into consideration the total costs of ownership (all operating and support costs, as well as the acquisition price) for the useful life of the system. The purpose of LCC is to obtain the best performance for the lowest total cost of ownership. This implies that cost/benefits trade-offs may result in an optimum, rather than a minimum LCC.

The use of LCC assumes that the decision concerning the acquisition of a weapon system is to be made by evaluating total LCC, and choosing the system from among those providing a given level of effectiveness and having the lowest LCC. The validity of this assumption rests on a presentation of the acceptability of a temporal transfer of the budget between years, without regard to the amount to be spent in any one year. Further, it is presumed that the probability of war is low, or so far in the future, that the decision can focus on peacetime costs only.

B. WEAPON SYSTEMS LIFE CYCLE COST

The life cycle of a weapon system is illustrated in Figure 1. The pattern reflected, and the life cycle phases depicted, are common to weapon systems. This section makes explicit a common framework for cost communication at all levels where cost analysis is performed.

1. Weapon Systems Definition

A weapon system consists of all items (including: ships, tanks, self-propelled weapons, aircraft, etc.; and related spares, repair parts, and support equipment; but excluding real property, installation, and utilities) necessary to equip, operate, maintain, and support military activities, without distinction as to its application for administrative or combat purpose. [Ref. 3]

Therefore, a weapon system is a composite of equipment, skills, and techniques which function together as an entity, capable of performing an operational role in response to an identified defense need. [Ref. 4]

The boundaries of different weapon systems may seem to vary, but the key words in the above definition, "functioning together as an entity", serve to define the system. For practical purposes, it is possible to define a weapon system at ship level or lower. For example: a ship with its operational crew and its maintenance personnel would constitute a functional entity.

In some cases there may be difficulty in deciding which costs should be attributed to a weapon system. The applicable principle is: If a given component would not exist if the system did not exist, then that component must be included in the definition of the weapon system.

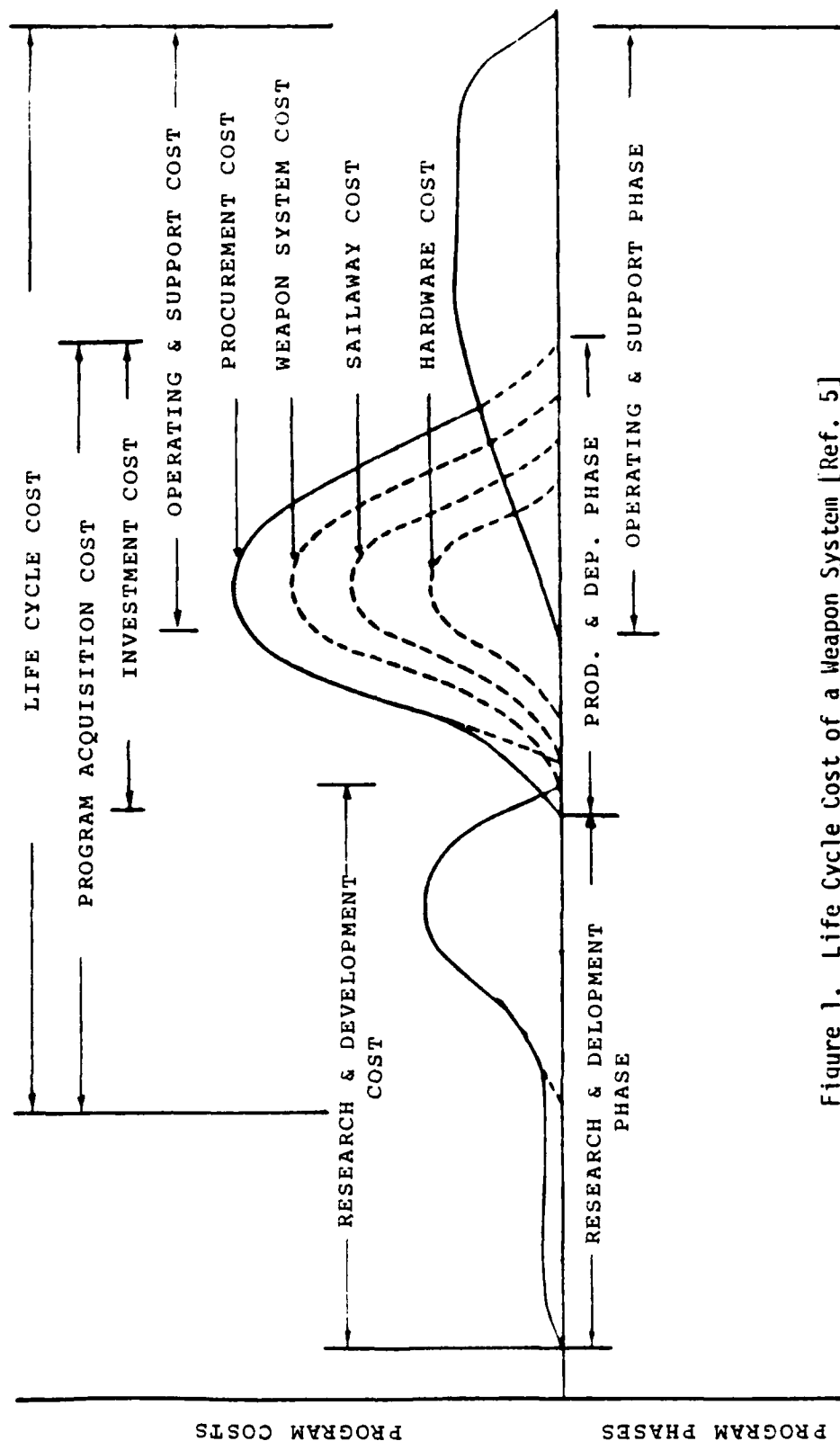


Figure 1. Life Cycle Cost of a Weapon System [Ref. 5]

2. Weapon Systems Life Cycle

Blanchard [Ref. 6] gives the concept of the life cycle as follows:

"A system, to be useful, must satisfy a need. However, designing a system to just meet the need is not usually sufficient. With few exceptions, the system must be able to continue to meet the need over a specific period of time in order to justify the investment in time, money, and effort. Thus one must consider a system in a 'dynamic sense'."

Specifically, for a weapon system, the life cycle is the period which begins with threat analysis and the need for the weapon system, and ends with its disposition. The major periods in the life cycle are indicated in Figure 2.

a. Planning Period

(1) Concept Formulation Phase. This is the initial phase of the life cycle in which efforts are directed toward analyzing the need (threat), identifying an evaluating feasibility of possible solutions to the need, and developing the operational requirements in sufficient detail to build a basis for the system definition phase.

(2) System Definition Phase. In this phase, the selected approach defined in the concept formulation phase is further refined, and its technical, economic, and financial feasibility is investigated in detail. The output is a set of system requirements communicated in a system specification for the proposed-on engineering development (system design) effort. Therefore, system definition translates system operational requirements into system design requirements.

b. Acquisition Period

(1) Design Development Phase. The Design Phase (research, development, test, and evaluation) encompasses that portion of the

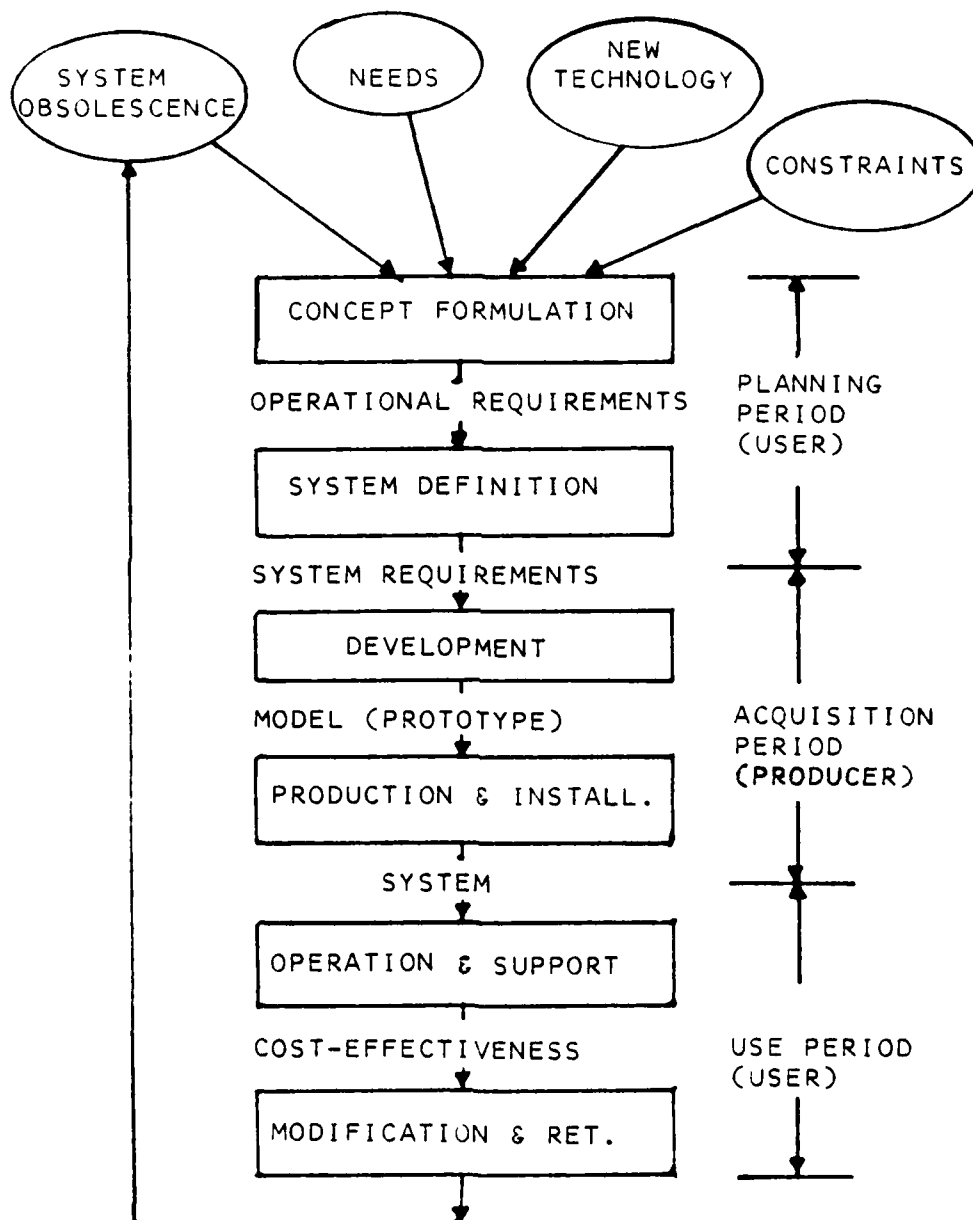


FIGURE 2. MAJOR TIME PERIODS OF A WEAPON SYSTEM LIFE CYCLE
[Ref. 7]

acquisition period during which the major system's design cost and time effort occurs. The requirements specifications identified in the planning period are inputs to the engineering effort. The output is a model of a system configuration, demonstrated and evaluated to meet optimum requirements based on specifications generated in the system definition phase.

(2) Production and Installation Phase. The production phase is the portion of the system life cycle wherein the system is authorized for mass production. If necessary, design improvements also may be introduced during this stage, based on quality assurance and reliability measurements of produced systems. [Ref.8]

The installation phase follows the production phase. The system cannot be considered operational (ready for use) until installation has been completed and the system is checked. The first time a system exists as a complete usable entity is after it has been installed with all of its required resources (prime equipment, facilities, and trained operating and support data).

c. Use Period

The use period of a weapon system is that period of time where the system can be operated to fulfill its mission requirements. It is during this period that the true cost-effectiveness of the system can be measured. The user has absolute responsibility for the system, and must be able to give logistical support.

Finally, when a system no longer proves cost-effective to meet either existing or modified operational requirements, it should be retired. The obsolescence of an old system usually generates new

weapon systems requirements, and another system life cycle starts.

[Ref. 9]

3. Weapon Systems Life Cycle Cost Structure

a. Research and Development (R&D) Costs

Research and development costs refer to all costs associated with research, test, and evaluation of the system. Specifically, these cover all costs during the concept initiation, validation, and full-scale development phases of the program.

R&D costs are divided into nonrecurring and recurring costs. During this phase, nonrecurring costs refer to one-time costs. If there is a change in design, or if contractor or manufacturing costs vary, additional costs may be incurred. Recurring costs include those R&D costs that occur with each unit (engineering/development test model) produced by the contractor. These costs tend to be subject to a learning curve concept in which the cost per unit decreases as the quantity produced increases. [Ref. 10]

b. Investment Costs

Investment costs refer to those program costs required beyond the development phase to introduce into operational use a new capability: to procure initial, additional or replacement equipment for operational forces; or to provide for major modifications of an existing capability. Investment costs are further divided into non-recurring and recurring costs.

c. Operating and Support Costs

This category includes the costs of personnel, material, facilities, and other direct and indirect costs required to operate, maintain, and support the system during the operational phase. It

Includes the cost of all parts consumed in maintenance of the equipment, as well as costs to maintain the necessary supply systems for parts, components, equipment, and information. [Ref. 11]

By developing and estimating the total costs of a piece of equipment or a system over its projected economic or operational life, it is possible to develop relationships between selected characteristics of an item of equipment or a system, and the costs which are a direct result of those characteristics. In deriving a cost-estimating relationship, the degree of decomposition of life cycle costs is dictated by minimizing the variance of the estimate. That is, very little decomposition would be expected in arriving at an LCC by means of a parametric estimate. Conversely, for effective management of a system, greater variance of LCC would contribute to increased inaccuracy in budget preparation.

III. PROPOSED METHODOLOGY FOR SHIPS LCC ANALYSIS

The guidelines recommended in this chapter were developed for the cost analysis of surface combat ship acquisition programs for the Venezuelan Navy. Generally they are appropriate for other surface ships such as auxiliaries and amphibious ships, and can be applied to submarine acquisition programs as well. Also, the same methodology can be applied in the cost analysis for procurement of a broad range of weapon systems. These guidelines call for cost estimates reflecting costs that are variable with respect to acquisition program decisions, therefore the estimates are not the same as total program or budget costs.

A. COST PERSPECTIVE

1. Cost Category of Interest

Taking into consideration that Venezuela acquires most of its ships from other countries where these ships already have been developed, produced, tested, and deployed, this recommended guideline addresses only SI and O&S costs.

The major life cycle cost categories for a ship are outlined in Table 1. Individual cost elements for these categories are defined in Appendix A.

2. Relevant Variable Costs

All relevant variable SI and O&S costs to the Venezuelan Government must be specified, regardless of how such costs are funded. The O&S cost categories reflect the recurring outlays required to operate and support a ship to achieve the desired capability over a specific

TABLE 1 (APP. A)

<u>SHIP LIFE CYCLE COST CATEGORIES</u>	
100.	RESEARCH AND DEVELOPMENT (R&D)
200.	INVESTMENT (SI)
201	System Investment
202	Conventions and Modernizations
203	Support Investment
300.	OPERATING AND SUPPORT COSTS (O&S)
301	Direct Unit
302	Direct Intermediate Maintenance
303	Depot Maintenance
304	Depot Supply
305	Second Destination Transportation
306	Personnel Support and Training
307	Sustaining Investment

operational lifetime. The set of SI and O&S categories is intended to be a comprehensive definition of the relevant variable costs. However, future analyses are bound to introduce circumstances in which additional costs will be factors. To cover these possibilities, the following rule must be applied: If a decision will affect costs not described explicitly by these guidelines, such costs must be identified, their magnitudes estimated, and they must be included in the cost analysis.

3. Relationship to Planning, Programming, and Budgeting

Cost estimates used for planning, programming, and budgeting address total costs. Because the cost analysis called for in these proposed guidelines pertains only to those portions of total costs that are variable with the acquisition of a new ship class, the estimated SI and O&S costs will not be necessarily the same as program or budget costs. However, the information gained from these SI and O&S costs analyses should be compatible with approved Planning, Programming, and Budgeting Systems (PPBS) costs, and can be used to derive the impact on programs and budgets.

B. COST ANALYSIS METHODOLOGY

Figure 3 outlines the basic cost analysis methodology for these suggested guidelines. The development and presentation of the cost analysis involves ten fundamental steps, organized into three groups. The major headings state the functions within each group. Arrows indicate the necessity for repeating individual steps to refine perception and assessment of critical issues. Most of the steps are standard components of systematic cost analyses. [Ref. 12]

1. Defining the Pertinent Issues

Each acquisition program is likely to entail special cost analysis issues. To deal with them, the analyses and presentations must be effectively tailored. The initial discussion should cover:

- a. Description and characterization of the proposed ship.
- b. Specification of an existing ship, and ship systems as reference systems.
- c. Specification of alternative candidate ships.
- d. Identification of historically relevant SI and O&S cost drivers for proposed systems, and actions planned to reduce them.

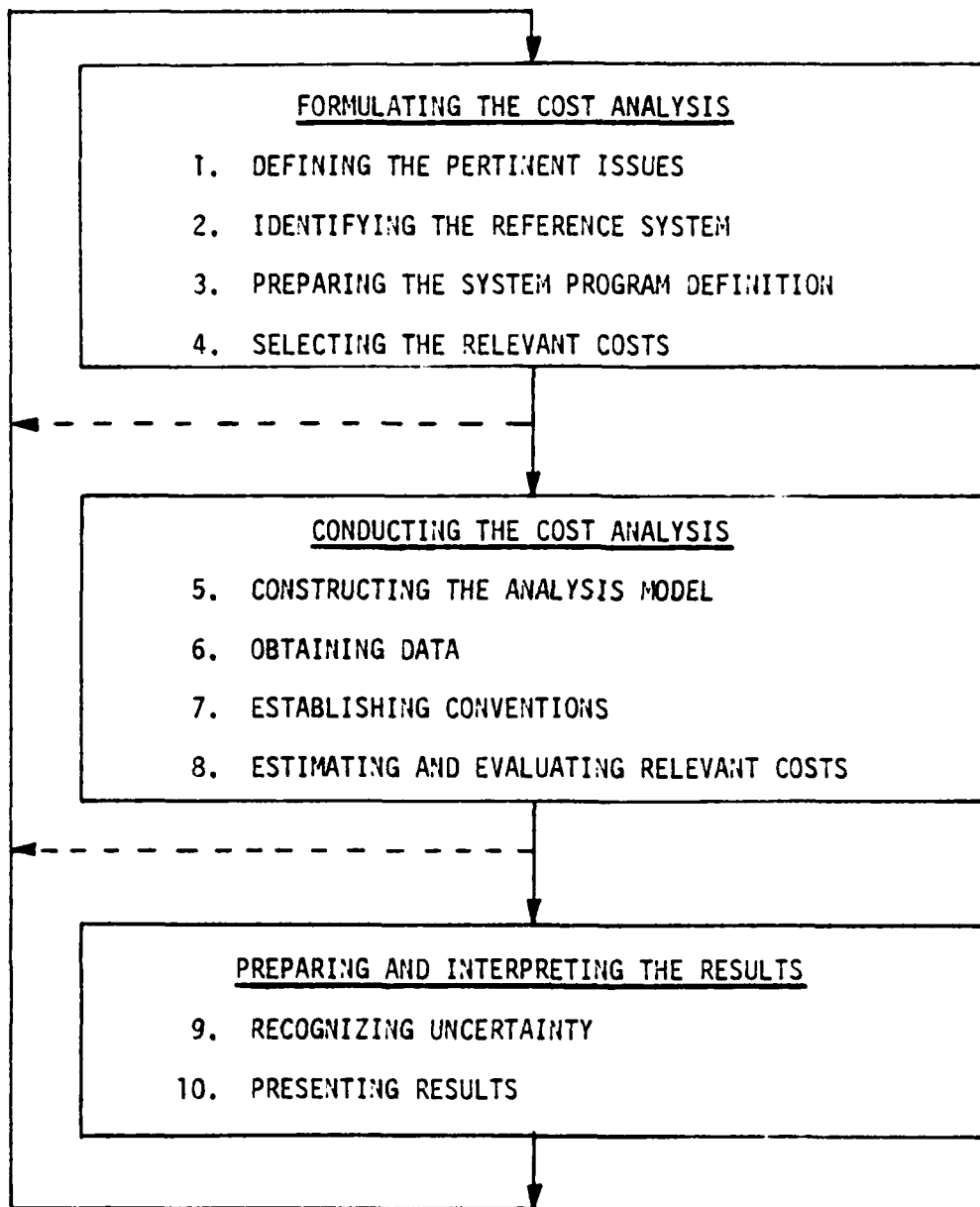


Figure 3. Basic Cost Analysis Methodology [Ref. 13]

- e. Identification of unique properties of the proposed system that could affect SI and O&S requirements.
- f. Specification of content and ground rules for the cost evaluation and its presentation, including determination all relevant variable costs and the applicability of those indirect cost elements contained in the collateral cost element structure (Appendix B).
- g. Specification of significant trade-off issues to be quantified and presented.

2. Identifying the Reference System

a. The Reference Ship

To provide the required contemporary baseline against which to compare costs, a reference ship must be identified. A reference ship is an existing ship having a mission similar or analogous to that of the proposed ship class. Frequently, the ship to be replaced is the reference ship, unless another existing ship provides a better point of reference for the cost analysis.

b. Benchmark Systems

A proposed ship O&S costs are not simply the sum of the costs of its subsystems. Certain costs are not directly allocable to subsystems, nor do they have requirements that combine in a nonlinear fashion. For example: Manpower costs for a ship as a whole might be 10 to 20 percent lower than the aggregate subsystem requirements because of cross-utilization of personnel (e.g., personnel with administrative support rating standing CIC watches).

However, cost estimates for proposed ship acquisitions should be developed to the extent feasible in terms of the costs of their subsystems. The preferred method is to use benchmarks, which are defined as operational subsystems similar to those proposed for candidate ships configurations. Benchmark subsystems cost experiences can

be applied to candidate ship subsystems through standard cost-estimating techniques such as direct analogy, scaling, developing cost-estimating relationships (e.g., parametrics), or engineering analysis.

3. Preparing the System Program Definition Statement

A prerequisite to the development of useful SI and O&S cost estimates for proposed ship programs is a detailed definition of a weapon system program. The System Program Definition Statement (SPDS) must:

- a. Reflect how the Navy will use and support the ship class.
- b. Supply essential assumptions and information for the cost estimates submitted.
- c. Provide historical data on the evolution of the design of the ship, and corresponding SI and O&S cost estimates from the beginning to the completion of the process.
- d. Establish a basis for critical review of mission requirements, and how well the proposed system design and support concept will satisfy them.
- e. Highlight the design areas with high technological risks and cost uncertainties.

In particular, the system program statement should include descriptions of the ship's mission, physical characteristics, manning, maintenance support policies, and acquisition policy. A basic outline for a SPDS for ships is presented in Appendix B.

4. Selecting Relevant Costs

A Cost Element Structure (CES) establishes a standard vocabulary for identifying and classifying the variable costs relevant to a weapon system program. The cost element definitions are given in Appendix A.

5. Constructing the Cost Analysis Model

Specific models for calculating SI and O&S costs are not prescribed in these guidelines. There are several ways of generating SI

and O&S cost estimates, and no one approach is best for all situations. In general, the problem context and cost analysis considerations determine the process selected. The problem context includes the phase of the acquisition program, the decision to be made, and the accuracy and resolution required in the estimate. A full explanation for the use of cost models is presented in Chapter IV.

The following criteria are useful for comparing and selecting cost estimating models:

- a. Decisions involving trade-offs must use techniques that emphasize cost differences between alternatives. Affordability estimates used as inputs to budget impact analysis may utilize macrotechniques that emphasize a system level perspective.
- b. For trade-off or program decisions, the cost-estimating technique must provide the accuracy required to distinguish the relative cost consequences of alternatives. Such accuracy is a function of the design maturity of the system or subsystem, the cost consequences of the decision and the data, and time available for making the decision.
- c. The cost models must provide subsystem visibility by associating relevant cost to subsystems, and must be sensitive to specific subsystem characteristics and differences between alternatives.

6. Obtaining the Data

In the context of these guidelines, data are facts or assumptions about the ship's characteristics, the way it is operated and supported, and the costs or essential resources (e.g., fuel, manpower, spare parts, etc.) associated with it.

For proposed ships, the Navy and the participating contractors will be the principal data sources. The Navy will be the principal data source for existing ships. These data will provide a basis for both the estimation of O&S costs, and an assessment of the predominant

cost driver subsystem and elements. Of particular interest are data that could be used to establish cost reduction targets in the design and support concepts for the new system.

The following data sources can be used: established reports, opinions and judgment of experts, observation and tabulation of steps in a work process, outside organization, and information centers.

7. Establishing Conventions

a. The Normative Approach to Cost Estimating

These recommended guidelines focus on the relevant variable costs that should be incurred by a specific weapon system under the O&S conditions specified in the SPDS; they are not designed to estimate future budget expenditures directly. The difference is important. An estimate of actual expenditures presumes the ability to predict the behavior of institutions that control resources allocation and expenditures. The normative approach used here only attempts to estimate what the future variable resource requirement should be given certain assumptions about the characteristics of the ship, the tactical doctrine for deployment, the support policies, the intensity of operations, etc.

The normative approach applies to an existing ship used as a reference ship, as well as to alternatives for the acquisition program. Insofar as practical, the assumptions and cost-estimating methods should be the same for both the reference ship and proposed candidate ship.

b. Use of Constant Dollars

Future costs should be estimated in constant budget year dollars of the fiscal year following the calendar year of the cost estimate. For example, if a SI and O&S cost-estimate is made during

calendar year 1981, then the cost-estimate should be presented in fiscal year 1982 constant dollars.

c. Mature System Assumptions

The O&S characteristics of a weapon system change throughout its lifetime. As the weapon system matures, O&S requirements should approach a level more indicative of its design characteristics than was the case earlier in its development. When estimating typical annual O&S costs, a mature ship should be assumed. The characteristics of the mature system are those most likely to occur, and they might not always be the same as the design goals.

When developing a time-phased estimate, the expected rate of maturity must be considered, as well as the rate at which new ships will be added to the fleet.

Different rates of maturity are particularly significant when comparing alternatives that differ markedly in their use of common subsystems, in the effort devoted to finding and correcting design or support weaknesses, in the support strategies for the early years in the systems' lives, and in the rate at which operating experience is gained.

d. Personnel Costs

Military and civilian personnel costs are the largest component of weapon systems O&S costs. The treatment of personnel costs is therefore central to the decision process.

When conducting O&S cost analyses, the military pay and allowances rates established for the Ministry of Defense should be used for military personnel. The rates published for the Central Personnel Office should be used for civilian personnel.

e. Capital Investment Lead Time Considerations

Requirements for SI items (e.g., support equipment, facilities, repair spares, etc.) are determined by the mission scenario, buildup schedule, workload, etc. When the requirements are interpreted in terms of budget appropriations, explicit procurement lead time allowances must be incorporated.

For the constant year dollar estimates called for by these guidelines, the aggregated sum of the SI will be the same regardless of whether or not lead time allowances are incorporated. However, presentations of time-phased cost estimates should be reflected for those years when the appropriation most likely would be made.

8. Estimating and Evaluating Relevant Costs

The analysis of O&S costs is vital to the selection, improvement, control of design, development, and support concepts for the proposed weapon system. The purpose of the O&S cost analysis recommended here is to: first, to explore and quantify the relative advantages of different concepts (i.e., the comparison of new and old systems, alternative support policies, etc.); and second, to provide a means of estimating the impact of O&S costs upon affordability and force structure planning. A fundamental consideration in the process is that the proposed ship satisfies its mission requirements at the lowest O&S cost commensurate with the overall LCC and performance criteria.

The cost analysis and its formulation (e.g., parametrics, scaling, etc.) needed for a specific program review will depend on the characteristic of the ship and the stage of the acquisition program. Frequently general types of analysis are required.

a. Cost Analysis

Cost analysis is used to determine the full set of relevant variable costs and how they compare between the reference system and program alternatives, and the expected to require the O&S resources estimated.

b. Trade-off Analyses

Trade-off analyses are used to explore cause-effect relationships between costs and changes in design or support concepts. A special kind of trade-off analysis, Operating and Support Requirements (O&SR) analysis, is recommended here. O&SR analyses are directed toward such issues as the effect of design characteristics and support policies on maintenance costs, and of ship system performance on manpower costs. They often are significant in the selection of subsystems, evaluation of support policies, and establishment of O&S goals.

c. Sensitivity Analysis

Sensitivity analysis is used to identify aspects of the acquisition program important in controlling O&S costs. It can influence such activities as establishing O&S goals and determining test and evaluation requirements.

Basically, a sensitivity analysis is performed by systematically comparing the inputs to the cost model, and noting the effects on the output cost estimates. By doing this, it is possible to identify those portions of the cost estimate that require further refinement, and to identify areas of risk.

d. Statistical and Budget Uncertainty Analysis

Statistical and budget uncertainty analysis is used to interpret and present the uncertainties inherent in the particular

cost model and its application (technical, demand, statistical, and budget assumptions) to determine how they will affect the program budget.

e. Trend Analysis

Trend analysis is used to compare the proposed ship with its historical counterparts. Of particular interest are comparisons of hardware subsystems, design characteristics, support policies and procedures that have historically dominated O&S costs, extent of departure from historical practices, and actions planned to reduce the consumption of O&S resources. Historical trends for the ship class (including the reference system) can be used to establish O&S bounds and goals for selected characteristics of the proposed system. For each significant cost element, the principal costs drivers can be classified by:

- (1) Hardware Subsystems (e.g., armament, propulsion, command and surveillance, etc.).
- (2) Design Characteristics of the Subsystem (e.g., limited modularity, poor fault diagnosis accuracy, etc.)

f. Support Policies and Procedures (e.g., level of repair decisions, etc.).

Each historical cost driver thus identified should be accompanied by an explanation of whether or not the problem is expected to occur in the proposed ship, and what actions would be necessary to control and/or reduce the future requirements for the proposed ship. The trend analysis then can be used to establish bounds within which the characteristics of the proposed ship would be considered normal, and to establish goals for reduction of O&S requirements.

9. Recognizing Uncertainties

Estimates of future O&S costs can vary due to uncertainties from many sources:

- a. Quality of data available
- b. Methods used to estimate costs
- c. Decisions yet to be made about design or utilization
- d. Changes in the scope of the acquisition program (e.g., quantities, costs, or schedule)
- e. Technical or technological problems encountered during development.
- f. Operating and support environment
- g. Characteristics that will become evident only after years of operational experience.

No O&S cost analysis can consider all of these uncertainties, nor does it need to. Many variables in an O&S cost estimate can be treated deterministically as long as explicit assumptions made about their values are reasonable, and parametric comparisons are used to explore the impact of changes. It is essential that presentations quantify the degree of uncertainty associated with cost estimates, whenever practicable.

Presentation formats should provide a quantitative range for the estimate. Use of a range is a simple means of showing uncertainties attributable to a point estimate. When a range is used, backup material should include an explanation of the method used to establish the bounds of the range. When quantification of uncertainties proves infeasible, a qualitative assessment of the estimate should be made.

10. Presenting Results

The goals for cost presentation are twofold: to present timely and relevant results, and to place them in proper perspective. There must be a logical consistency underlying all the presentations throughout the process to insure that the outputs and trend data generated in the cost analysis can be tracked.

IV. USE OF COST MODELS IN LCC PROCUREMENT

A. INTRODUCTION

Life Cycle Cost is a costing discipline, a procurement technique, an acquisition consideration, and a trade-off tool. [Ref. 14] As a costing discipline, it is primarily concerned with O&S cost-estimating methods. As a procurement technique, it deals with minimizing total LCC for component procurements. As an acquisition consideration, its primary concerns are source selection, and the balancing of acquisition and ownership costs. As a trade-off tool, its main considerations are repair levels, and the impact of specific design features on O&S costs.

The main tool in an early analysis of O&S costs is the use of LCC models. The definition of LCC that appeared in a previous chapter is conceptually simple in that it includes all development, production, maintenance, operation, personnel costs, etc., in the life cycle calculation for every system. However, trying to calculate all of these cost elements is difficult, even with the current techniques. The data needed for a unique system is not available in many instances. In any case, the LCC estimates are only as good as the assumptions, theories, empirical relationships and data upon which they are based. [Ref. 15]

LCC models have become the most common and useful techniques utilized in structuring the cost accounting package used to support bid prices during the contracting process.

B. COST MODEL DEFINITION

A cost model is comprised of one or more mathematical relationships arranged in a systematic sequence to formulate a cost methodology in which outputs (cost estimates) are derived from inputs (description of the equipment, organization, procedures, etc.). Cost models can vary from a simple one-formula model to an extremely complex model that involves hundreds, or even many thousands, of calculations.

As an example of a very simple cost model, the cost of an item might be related directly to its weight, that is: $C = D \times W$

where, C = Cost of an item in dollars

D = Cost in dollars per pound of weight

W = Weight in pounds

Here, D and W are inputs to the model, and C is the output. Although this is a very simple model, nevertheless it performs the function of providing a cost estimate for a given input.

Because the term "cost model" is used in many different contexts, it can have a variety of specific meanings. In all cases it is a device designed to obtain a cost estimate. In brief, it is more or less an abstract representation of a part of the real world based upon insights into the cause-and-effect relationships existing in that world.

There are various kinds of cost models. LCC models are distinguished from other cost models in that the former always reflect subsequent costs, which are the direct consequence of the decision or action being contemplated, including operating and support costs, rather than merely the initial acquisition cost. [Ref. 16]

C. ADVANTAGES AND LIMITATIONS OF COST MODELS

1. Advantages

There are a number of advantages provided by the use of cost models in the solution of acquisition problems. Inherent in the process of constructing a cost model is the development of a framework for analysis. This, in turn, provides an analytical consistency for solving problems. Another benefit derived from a model is the ability to determine how sensitive one factor is to change in other factors, i.e., sensitivity analysis.

2. Limitations

Most cost models are expressions of direct mathematical relationships among defined variables, and the output is determined when the inputs are furnished. However, these inputs are numerical values which are only best estimates of what is expected to happen. The model should not be viewed as a source of the only output that is correct. To be useful, a model must be an adequate representation of the current real world. This means that a model has to be maintained. It must have the best numerical values for all stated parameters. Failure to keep it updated will affect its utility adversely. [Ref. 17]

D. DISCOUNTING OF COST FLOWS

Whenever the costs included in a model occur over a certain period of time, such dollar values are not equal. Resources today usually are worth more than the identical resources deliverable tomorrow. Consequently, the dollars with which resources are bought today are worth more than those same dollars if they are not available until tomorrow. Therefore, before dollars spent or received in different periods can be totaled, future dollars must be discounted, because they are worth less.

Quade [Ref.18] refers to the procedure for discounting as follows:

"Discount is calculated exactly the way the banks do it. If the discount rate is 6 percent, the bank will give us \$1.06 in one year for a dollar today. The cost of the program which does not require that the money be laid out until sometime in the future must be discounted, if it is to be compared with an alternative where the money is to be paid today. By discounting the value of future dollars we can then compare the programs for which the expenditures come at different times."

The proper choice of a discount rate depends on the alternatives, just the same as costs do. In turn, these alternatives depend upon the decisionmaker's authority and interest. The appropriate discount rate for use in comparing future dollars with today's dollars depends upon the alternative opportunities available exchanging one for the other.

V. CRITERIA FOR DECISIONMAKING UNDER THE LCC CONCEPT

Of all the managerial functions which executives perform, whether at top, middle, or lower level, the act of making a decision is without equal in importance. That is to say, it is the act of making the right decision about the right problem or opportunity. [Ref.19] In decisionmaking, cost is always a key factor. As one step in the decisionmaking process, the cost of one alternative must be compared against the costs of other alternatives. [Ref.20]

In weapon systems acquisition, the decisionmaking process is influenced by two basic considerations: Life Cycle Cost and System Effectiveness. This thesis is concerned only with the LCC aspects of the decision process. In this chapter a contrast is presented between the current procurement criteria actually in practice within the Venezuelan Navy, and the decisionmaking process under the concept of LCC.

A. THE CURRENT PROCUREMENT CRITERIA

In the Venezuelan Navy, the procurement process for any weapon system begins with the need, which is principally based on an existing threat, or forecast of a future threat. In this context, a threat is defined as any phenomenon that may interfere with the Navy's basic missions, goals, and responsibilities. Needs also can arise as a result of an operational deficiency due to changing mission objectives, changes in environment, or obsolescence of weapon systems currently in use.

The criteria for decisionmaking actually used by the Venezuelan Navy in the procurement of weapon systems relies on the trade-off between

system effectiveness and minimum procurement cost, with little or no consideration being given to O&S costs that are not going to be encountered until the system is included in the inventory. Realistically, there is very little organizational incentive to minimize O&S costs when the decision variable is the minimum procurement cost.

Additionally, the Venezuelan Navy's force structure is managed by units, and not by weapon systems. This means that identification of a particular weapon system's O&S cost is extremely difficult to determine accurately. The absence of readily retrievable data for O&S costs leads the decisionmaker to focus on procurement costs alone.

B. THE DECISION INFLUENCED BY LCC.

The tendency today is to build a system management process in which cost considerations, taken in conjunction with considerations of system effectiveness and schedules, will properly influence virtually all decisions. Perhaps the most important decisions of all will be the choice among alternatives in the following areas: contractual requirements, both qualitative and quantitative hardware and software design; proposed product improvement effort; and preventive maintenance programs. Corrective maintenance decisions must be made such as: throw-away versus repair of failed equipment; personnel; support systems; operating procedures; in short, virtually anything that can influence the life cycle costs and/or effectiveness of the system. [Ref.21]

1. Predominant Decision Considerations

When interpreted in its broadest sense, the phrase "cost-effectiveness analysis" conveys the major ideas which govern decision-making in systems acquisitions. In choosing among alternatives, the

decisionmaker should consider everything that will affect future costs for each alternative, as well as every future benefit or achieved objective that will result from each alternative. This should include, as finitely as possible, all costs in forms other than dollar value, (i.e., commitment of such other existing resources such as buildings or land, or such intangible costs as departure from a strong precedent), especially where they differ between alternatives. It also should include all possible types of benefits, both tangible and intangible, which may occur at any future time during the life cycle of the system, including special system effectiveness. (System effectiveness is the analysis of a system's potential and/or capacity to perform its assigned mission.)

2. Sensitivity of Decision to LCC

The impact of LCC is that its use sometimes will lead to a preference for a decision different than that which might be made if cost considerations were limited to initial procurement cost. The LCC value, as estimated at any point during the acquisition process, may indicate that the total cost of the contemplated system is excessive in relation to the anticipated benefits. In such cases, the LCC consideration may lead to a program discontinuance, reduction, simplification, or replacement by an alternative approach.

A second type of impact is shown in Figure 4. This Figure illustrates a case in which alternative A, with higher initial cost than alternative B, leads to a flow of subsequent or "consequential" costs which are sufficiently smaller so as to make the total cost of A lower than B. Assuming that the benefits from both A and B are

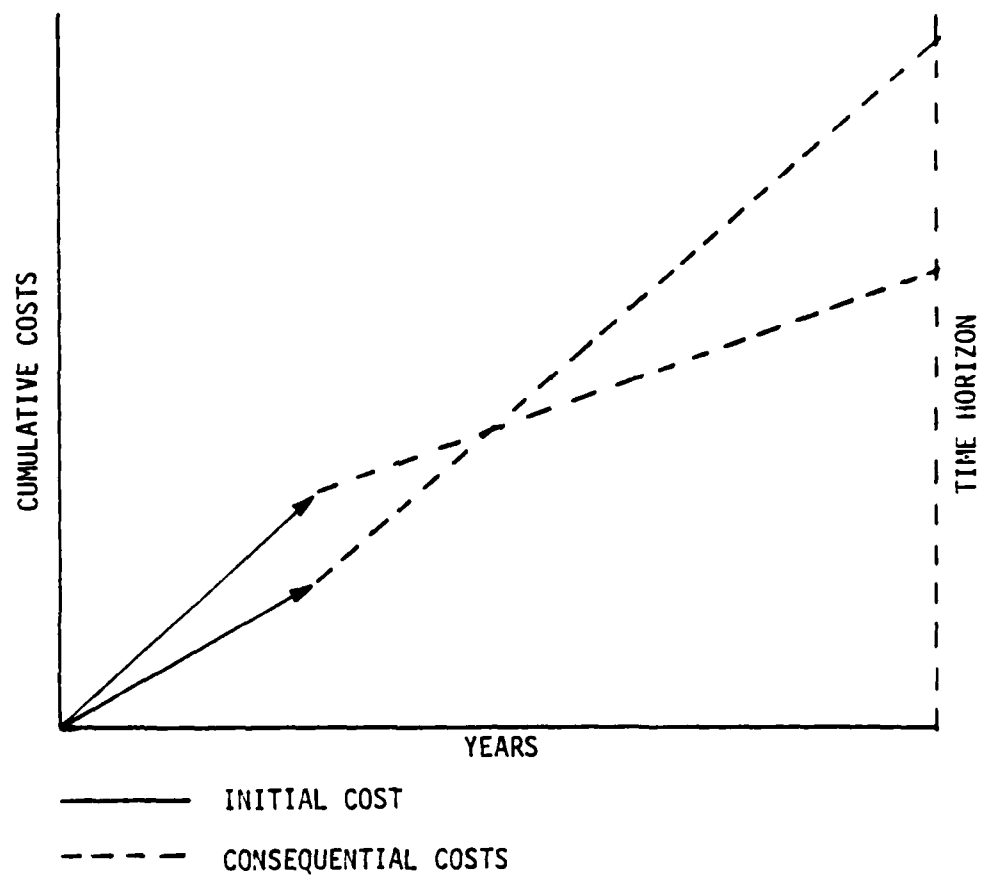


Figure 4. Cumulative Costs over Time [Ref. 22]

equal, use of the LCC approach will lead to a choice of A for the "time horizon" shown; whereas, without LCC the choice would be B. However, the choice of a higher initial cost item sometimes may be constrained by short term budgetary limitations, or by other considerations such as manpower or investment policies. In such cases where it appears that the full advantage of LCC cannot be achieved within these constraints, the policy authority should be advised to afford an opportunity to remove the constraint.

Selection of the time horizon can be a critical element of the LCC decision process. This selection should be made carefully in each application, and be based on the expected or intended life (or lives) of the alternatives under consideration. The choice of the time horizon will determine whether the cumulative cost lines cross during or after that life. Equally important, the time horizon also influences the quantitative difference between the LCC values. In the cost-effectiveness analysis, it is that quantitative difference in cost which is compared to a quantitative difference in effectiveness to help make correct decisions. [Ref. 23]

3. Multiple Criteria and Common Units

As the number and diversity of trade-off criteria increases, the determination of preferences between alternative choices (each of which gives one combination of the criteria) rapidly becomes more complex. It is therefore necessary to manage the decision process so as to reduce to a minimum the number of criteria which influence the decisionmaking. This is most difficult when important criteria cannot be converted easily to common units, but it should be pursued as far

as possible whenever criteria can be measured in (or converted into, or incorporated within) common units. An example of this approach would be where the Navy specifies overall performance requirements instead of detailed design specifications. The ultimate along these lines would be the conversion of everything possible to the minimum number of criteria, that is, to LCC and to system effectiveness.

The use of dollars as one key measurement unit in this context does not imply an inordinate concern with economics or budgets at the expense of military security. Rather, the dollars serve as a measurement tool which provides a common medium of exchange, and thus expedites "trading". This tends to replace a direct and cumbersome barter system, much the same as money does in the marketplace.

4. Balance Between LCC and System Effectiveness

Consider a case in which the guidelines presented in this paper are applied so that payments to the contractor will be affected by his demonstrated success with LCC, for example, through an incentive clause. Such an arrangement conceivably could cause LCC considerations to become more influential than system effectiveness unless steps are taken to preclude this undesirable development by also including balanced monetary arrangements in the contract, which depend upon demonstrated success in system effectiveness. In general, although LCC is intended to correct past under-emphasis on recurring support costs, trade-offs between cost and effectiveness must be managed with the utmost care.

It is possible to think of system effectiveness either in terms of an entire organization, or in terms of the effectiveness of individual items of equipment, i.e., ships, tanks, aircraft, etc. In th

latter case, greater or lesser achievement per item of equipment is almost certain to lead to comparably greater or lesser achievement at the level of the total organization. Also, it is possible that the size of the organization will be adjusted instead. Thus, if each individual piece of equipment will be more available, or dependable or capable, then compensating reduction might be made in the number of items to be procured. In this event, increased effectiveness of individual items will be reflected in terms of organizational LCC rather than organization-wide system effectiveness--as the latter could be held constant.

For this reason, an adaptation of the guidelines presented here could be so designed as to include performance "effectiveness per item" under the LCC management framework. For example, if the operational readiness per aircraft materializes at different percentages than was contracted for, the incentive formula based on demonstration for LCC could reflect the cost of a revised number of aircraft so that the original contract for operational ready-hours would be met, regardless of whether fleet size actually will be adjusted to reflect the achieved operational readiness per aircraft. [Ref. 24]

VI. METHODOLOGY FOR LCC PROCUREMENT

LCC can be viewed as a procurement technique in which competing systems can be evaluated by their total useful life cost rather than being based on the initial acquisition cost. Contractors must be informed that LCC will be a major consideration in the selection of a program, and contracts should contain clauses specifically addressing LCC. Implementation of this philosophy requires making O&S costs a real factor in source selection, with the objective of insuring that contractor's efforts result in adequate LCC estimates during the design process prior to full-scale development. Also, it may involve employing incentives such as warranties to emphasize design of reliable and low cost-to-support systems.

A. REQUEST FOR PROPOSAL

Preparation of the Request for Proposal (RFP) for a life cycle cost-oriented program involves several considerations which are different from other types of programs. The Venezuelan Navy's intent to use LCC as a source selection criterion for procurement should be stated clearly in the RFP. In addition, all other major source selection evaluation criteria should be included, indicating their relative importance.

The most desirable approach, time permitting, appears to provide a draft RFP to all competing contractors. The draft RFP should contain, as a minimum: source selection criteria, complete description and instructions for the LCC model to be used, contemplated incentive or Reliability Improvement Warranty (RIW) provisions, and provisions

regarding qualification and/or verification testing to be required. After prospective contractors have had a reasonable period of time to examine and evaluate the draft RFP, a bidder's conference should be scheduled so that all contractors are given the opportunity to present questions they may have about the RFP and the LCC approach to be used. This insures that all contractors will have the same information, and will be able to submit their proposals on an equal basis. Sometimes this approach has an added advantage of clarifying and improving the quality of the final RFP by allowing the program management team to incorporate worthwhile suggestions by the contractor.

As a general rule, the RFP should be as definitive as possible, containing specific line items for all known equipment requirements, options for increased quantities, ground support equipment(GSE), data items, reprourement data, warranties (if required), and any contractor field support that is anticipated.

In a competitive LCC procurement, thorough planning of the RFP is the key to program success at the lowest LCC. After the production contract award, normally the program is no longer competitive, and the winning contractor has little or no incentive to provide further reductions in ownership costs.

On the other hand, if the program is a sole source procurement, leaving requirements as flexible as possible may be beneficial. This depends greatly on the reputation and attitude of the contractor, and his desire for future business. If a contract is properly incentivized, a contractor may be motivated to develop and propose innovative and more reliable design approaches, economic maintenance concepts, and effective incentive arrangements. [Ref. 25].

B. SOURCE SELECTION

The specific objectives of LCC analysis during the source selection process are to:

1. Verify the accuracy of contractor's LCC calculations.
2. Verify that bidding contractors have a common interpretation of LCC provisions when submitting their proposals.
3. Disclose the relative differences in the calculated LCC and contractor support costs. [Ref. 26]

Accomplishment of this objective requires the assembly of personnel who possess a broad range of expertise in program management, material management, engineering, cost analysis, procurement, and contract law.

Use of LCC as a source selection criterion is of little value in motivating contractors to propose designs and approaches which will minimize ownership costs. Two approaches which have been beneficial in motivating contractors are independent cost and reliability estimates, and team visits to contractor's plants.

The independent cost and reliability prediction estimates may be accomplished either by in-house teams, or by consulting contractors or contracts in the program office. The point is that the contractor should be made aware that their proposals will be evaluated independently by at least one group that is completely separate from the Source Selection Evaluation Board. Since they know they will be evaluated by multiple organizations, this approach has proved to be effective in providing increased visibility, and in motivating contractors to provide accurate information.

Another approach is used while contractors are finalizing designs and preparing proposals for the production contract award. During

this phase, the LCC team from the Source Selection Evaluation Board is sent to the competing contractor's plants to evaluate reliability and maintainability factors, design approaches, and other LCC aspects of the procurement. This provides high visibility of the Navy's intent to use LCC as a major award factor, and very likely provides further motivation to the contractors to propose their lowest LCC designs.

[Ref. 27]

C. LIFE CYCLE COST TEAM FORMATION

Assembling a competent LCC team to evaluate contractor's proposals is a critical element in the source selection process. This team should include not only cost and modeling experts, but also mechanical, electrical, Naval, and system engineers. The goal of the program manager should be the assembly of a team that is capable of independent verification and analysis of all aspects of the contractor's proposal. If the desired personnel are not available within the Navy, consideration should be given to obtaining assistance from an independent contractor who specializes in whatever aspect of the LCC evaluation expertise the program manager requires. This may create a significant drain of scarce program resources, but unless the Navy can conduct accurate, independent analyses of contractor proposals, the advantages of LCC competition are lost.

Even after source selection, the LCC team will be helpful during the production and field verification testing by performing as consultants on various aspects of LCC such as engineering change proposal, and evaluation and maintenance problem analysis. Keeping the team together could be a significant problem as most members normally are

given new assignments after source selection has been completed. Program managers should attempt to maintain team identity, possibly on a part-time basis, at least until the completion of verification testing, because many LCC related questions and problems continue to be encountered throughout the program management process.

D. FINAL POINT

Signature of the contractual document by the government and the contractor culminates after long months, even years, of effort by the Navy program team. The contract specifies both government and contractor obligations which must be fulfilled to ensure that the program's objective is achieved.

The success in implementing LCC procurement depends to a great extent upon rigorous discipline in carrying out the government's obligations. These obligations are significantly greater than with a contract for the same equipment that does not contain life cycle cost procurement provisions. The importance of establishing and maintaining credibility cannot be overemphasized. In fact, the enforceability of the LCC contractual provisions are contingent upon the government carrying out its obligation. The final form of a contract will be contingent upon many factors such as the competitive situation, complexity of equipment, maintenance approach, incentive provisions, and qualification and/or verification testing requirements.

Normally, once the production contract is signed, the program is no longer competitive, and the contractor has no further incentive to reduce the Navy's ownership costs beyond what is required by the contract. [Ref. 28].

VII. CONCLUSIONS

1. Life Cycle Cost can be viewed as a procurement technique in which competing systems are evaluated on the total cost over their useful life rather than selection being based on the initial acquisition cost.

2. Implementation of the philosophy presented in this thesis implies that some change has to be made in the procurement criteria actually in practice within the Venezuelan Navy in order to make operating and support cost a real factor in source selection for acquisition of weapon systems.

3. The implementation of the Life Cycle Cost philosophy by the Venezuelan Navy can improve considerably the decisionmaking process in weapon systems acquisition programs. At the same time, a more rational view of future costs incurred by introduction of a new system into the organization can result in more accurate budget estimates.

APPENDIX A

BASIC COST ELEMENT DEFINITION FOR SHIPS [Ref. 29]

200 INVESTMENT: The sum of cost elements 201 through 205

201 System Investment: The "Sailaway" cost of the ship plus any other cost to the government of procuring the ship, managing the acquisition program, and providing for performance modifications. This element is the sum of subelements 201.1, 201.2, and 201.3.

201.1 Sailaway Cost: The cost of acquiring the basic ship as accounted for by these categories: basic unit, propulsion equipment, electronics, armament, other installed equipments, nonrecurring costs, and allowance for engineering change orders.

201.2 Project Management: The cost of personnel in the project management office who manage the ship acquisition program.

201.3 Performance Modifications: The cost of changes modifications, alterations, or other improvements in the ship's subsystems designed to enhance the performance or improve or alter the mission capabilities of the ship. The cost of changes, modifications, alterations or other improvements related to safety, habitability, maintainability, or technical aspects of the ship's subsystems is excluded. The categories covered by this

exclusion are more logically O&S-related and therefore will be included in the O&S elements 303.3 and 307.2, as appropriate. If it is not feasible to distinguish among modifications, then all modifications will be included in the O&S elements 303.3 and 307.2.

202 CONVERSIONS AND MODERNIZATIONS: The cost of major changes in a ship's configuration subsequent to commissioning that significantly alter the military characteristics of the ship, but are not accounted for by incremental improvements or subsystem modernizations accomplished during periodic overhauls. Conversions and modernizations are funded with the major acquisition appropriation, i.e., shipbuilding conversion. This element is the sum of subelements 202.1 and 202.2.

202.1 Sailaway Cost: The cost of acquiring the converted or modernized ship. (It is noted that much of the sailaway cost has been previously incurred, and therefore, those costs will be regarded as "sunk costs".)

202.2 Project Management: The cost of personnel in the project management office who manage the ship conversion or modernization program

203 Not assigned

204 Not assigned

205 SUPPORT INVESTMENT: The sum of elements 205.1 through 205.6

205.1 Support equipment: The cost of the peculiar and common support equipment procured to perform all three levels

of maintenance for these particular ships. This element is the sum of subelements 205.1.1 and 205.1.2.

205.1.1 Peculiar Support Equipment: The cost of the tools and test equipment, including portable equipment, which have application only to these particular ships, and are required to maintain them. An item of equipment may be required at all three levels of maintenance. Industrial plant equipment and the modification of facilities, which are covered under 205.4, are excluded. Installation of peculiar support equipment, if required at intermediate and depot levels, is covered under 205.4. This element is the sum of subelements 205.1.1.1 and 205.1.1.2.

205.1.1.1 Organizational: The cost of the peculiar support equipment to perform organizational maintenance.

205.1.1.2 Other: The cost of the peculiar support equipment to perform intermediate and depot level maintenance.

205.1.2 Common Support Equipment: The cost of the tools and test equipment procured to maintain these particular ships. Common support equipment is distinct from peculiar support equipment only in that "common" items are for support of more than one defense system. An item of equipment may be

required at all three levels of maintenance. General purpose hand tools and equipage, operating space items of a general nature delivered with the ship, and industrial plant equipment and the modification of facilities, which are covered under 205.4 are excluded. Only increments directly relatable to the maintenance requirement of the ship shall be considered. Installation of common support equipment, if required at intermediate and depot levels, is covered under 205.4. This element is the sum of subelements 205.1.2.1 and 205.1.2.2.

205.1.2.1 Organizational: The cost of common support equipment to support organizational maintenance.

205.1.2.2 Other: The cost of common support equipment to support intermediate and depot level maintenance.

205.2 Training: The cost of the initial specialized training of nucleus crews; and the devices, accessories, aids, equipment spares and repair parts for the instruction of navy personnel in the operation and maintenance of these particular ships. Training of a general nature, with Navy-wide applicability, such as fire-fighting, damage control, etc., or training related to particular subsystems currently in

use elsewhere in the Navy is excluded. Training devices, accessories, aids, equipment, and associated spares and repair parts delivered with the ship are covered under element 205.2.3. This element is the sum of subelements 205.2.1, 205.2.2, and 205.2.3.

205.2.1 Services: The cost of the instructors, training aids, and course materials for the initial training of Navy personnel.

205.2.2 Equipment: The cost of end items of training equipment, such as simulators, cutaways, muck-ups and models designed, developed, engineered, or fabricated to meet the training requirements at off-ship facilities.

205.2.3 Shipboard Training Aids: The cost of training devices, accessories, aids, equipment, and parts delivered with the ship.

205.3 Documentation and Software: The cost of the initial publications and technical data and automatic data processing (ADP) software for the operation and maintenance of these particular ships. This element is the sum of subelements 205.3.1 and 205.3.2.

205.3.1 Publications and Technical Data: The cost of the initial manuals and drawings, including technical documentation and data for operation and maintenance.

205.3.2 ADP Software Development: The cost of the initial development and installation of computer programs for the ship's operation and support systems and equipment.

205.4 Facilities: The cost of the construction, conversion, alteration, or modification of facilities and equipment for the maintenance, training, and logistic support of these particular ships. The procurement and installation (if required), of peculiar and common support equipment are included. Procurement of peculiar and common support equipment, which is covered under 205.1, and replacements for existing facilities are excluded. This element is the sum of subelements 205.4.1 through 205.4.4.

205.4.1 Repairable Component Repair: The cost of the construction, conversion, alteration, or modification of major facilities designed for the purpose of rebuilding, repairing, maintaining, or modifying spare components, assemblies, subassemblies, equipments or items, such as in the rotatable pool concept.

205.4.2 Industrial: The cost of the construction, conversion, alteration, or modification of naval shipyards or other facilities to accomplish depot level maintenance. Investments made solely for repairable component repair facilities, which should be reflected in 205.4.1 are excluded.

205.4.3 Training: The cost of the portion of construction, conversion, rearrangement, or expansion of facilities allocable to the ships to meet the training requirement.

205.4.4 Other Ashore Facilities: The cost of the construction, conversion, alteration, or modification of piers, docks, anchorages, fuel storage sites, ammunition depots, etc., to support operations.

205.5 Initial Spares and Repair Parts: The cost of initial spares and repair parts stocked for the service and repair of these particular ships. This element is the sum of subelements 205.5.1 and 205.5.2.

205.5.1 Spares: The cost of the initial spares to service and repair these particular ships. Recurring replenishment of spares is covered in 307.1. Spares are recoverable components, subassemblies, assemblies, equipments, or end items installed or placed in use while replaced items are undergoing maintenance, repair, or overhaul. This element is the sum of subelements 205.5.1.1 and 205.5.1.2.

205.5.1.1 Organizational: The cost of those spares carried onboard in accordance with ship's allowance list.

205.5.1.2 Other: The cost of those spares added to system stocks, specifically as a result of the ship's requirements. Those spares carried at intermediate activities in accordance with prescribed load lists are included.

205.5.2 Repair Parts: The cost of the initial repair parts to service and repair these particular ships. Repair parts are those individual parts for the maintenance or repair of installed equipment and spares. This element is the sum of subelements 205.5.2.1 and 205.5.2.2.

205.5.2.1 Organizational: The cost of the repair parts carried onboard in accordance with the ship's allowance list.

205.5.2.2. Other: The cost of the repair parts added to system stocks, specifically as a result of the ship's requirements. Those repair parts carried at intermediate activities in accordance with prescribed load lists are included.

205.6 Other Investment: The cost of the initial fill of expendable ordnance and war reserve stocks for these particular ships. This element is the sum of subelements 206.6.1 and 205.6.2.

205.6.2 War Reserve Stocks: The cost of supplies of specific spares and repair parts for war reserve requirements. (These costs should not be counted also in element 205.5. If the costs of war reserve stocks cannot be distinguished from the costs of initial provisioning reflected in element 205.5, they will be counted only in that element.)

300 OPERATING AND SUPPORT: The sum of elements 301 through 307.

301 DIRECT UNIT: The direct costs associated with the operation of the ship, composed of the sum of elements 301.1, Personnel, and 301.2, Material.

301.1 Personnel: The direct personnel costs at organizational (unit) level. These are the sum of subelements 301.1.1, Manpower, and 301.1.2, Temporary Additional Duty (TAD).

301.1.1 Manpower: The cost of the services of all active ship's personnel, computed at the standard rate. The standard rate includes the following elements: basic pay, quarters, subsistence, clothing allowances, incentive and special pay, and miscellaneous expense for the ship's personnel. Indirect personnel support costs are accounted for in 306.

Actual organizational maintenance manpower
May be separately identified, if feasible.

301.1.2 Temporary Additional Duty (TAD): The costs associated with the temporary assignment of shipboard personnel away from the ship for training, administrative duty, or other purposes. It consists of transportation, lodging, mileage allowances, per diem allowances, and incidental travel expenses.

301.2 Material: The cost of material expended or used by the ship and her crew during the ship's operational assignments and maintenance periods, except for those materials covered in 307, Sustaining Investments. It is the sum of subelements 301.2.1, 301.2.2, and 301.2.3.

301.2.1 Fuel: The cost of propulsion and ship's service fuel consumed by the ship.

301.2.2 Repair Parts: The cost of repair parts used in the organizational maintenance of the ship. Repair parts are those individual parts used for equipment repair, but not considered repairable in themselves. Repairable items, which are termed "replenishment spares" are covered in 307.1, and are excluded.

301.2.3 Supplies: The cost of consumable supplies (e.g., janitorial supplies, office material, personnel support supplies, medical and dental material, etc.), and equipage items (e.g., binoculars, clocks, etc.) not directly related to the support of specific equipment or systems. This element also includes oils and lubricants.

302 DIRECT INTERMEDIATE MAINTENANCE: The cost of the direct labor, material, services, and repair parts expended during afloat or ashore intermediate maintenance activity (IMA) availabilities. Direct labor is defined as the manpower specifically applied to those tasks necessary to accomplish maintenance and repair services for these particular ships. The cost of direct labor is construed to include basic pay, quarters, subsistence, clothing allowances, incentive and special pay, and miscellaneous expense. If these particular ships require particular IMAs, the cost associated with those IMAs must be shown; otherwise, average costs may be used. The direct IMA cost consists of the sum of elements 302.1 and 302.2.

302.1 Tenders and Repair Ships: The cost of material and direct labor expended by the tenders and repair ships in support of ships serviced. This element is the sum of subelements 302.1.1 and 302.1.2.

302.1.1 Labor: The cost of the direct labor expended by the tenders and repair ships.

302.1.2 Material: The cost of the material and repair parts expended by the tenders and repair ships.

302.2 Ashore IMA: The cost of the material and direct labor expended by ashore IMAs in support of ships serviced. This element is the sum of subelements 302.2.1 and 302.2.2.

302.2.1 Labor: The cost of the direct labor expended by the IMA.

302.2.2 Material: The cost of the material and repair parts expended by the IMA.

303 DEPOT MAINTENANCE: The funded costs of direct labor, direct material, other direct costs, and applied overhead chargeable to the job orders for overhaul, progressive maintenance, analytical rework, modification, repair, inspection and test, manufacture, reclamation, and storage of ship subsystems, components, parts and support equipment. The cost of similar work accomplished via contractor maintenance or interservice maintenance support also is included. Industrial facilities are to include commercial facilities, naval shipyards and other industrial facilities that perform depot level maintenance. Significant industrial maintenance costs incurred by contract will be separately identified where feasible.

(The ship's own repair parts expended by the ship's force during industrial availabilities will be included under 301.2.2. Material, parts, and labor used for supporting rotatable pols will be included in 303.6.) This element is the sum of elements 303.1, Regular Ship Overhaul; 303.2, Nonscheduled Ship Repair; 303.3, Fleet Modernization; 303.4, Selected Restricted Availability; and 303.5, Repairable Component Repair. For those elements of depot maintenance that call for a separate breakout of labor and material costs, aggregation of those costs at the next higher level of indenture is acceptable when such a breakout would be impractical.

303.1 Regular Ship Overhaul: The cost of the shipyard periods scheduled in advance for the accomplishment of major maintenance and repair. This is the sum of subelements 303.1.1 and 303.1.2.

303.1.1 Labor: The cost of the labor expended by the shipyard in support of ship serviced. The labor cost will be a fully-loaded cost to account for a pro rata share of direct, indirect, and overhead costs.

303.1.2 Material: The cost of the material and repair parts expended by the shipyard in support of ships serviced. (Replenishments which are covered in 307.1 are excluded.)

303.2 Nonscheduled Ship Repair: The cost of the maintenance and repair performed at shipyards or other industrial facilities resulting from casualties, voyage damage, etc. These are repairs between scheduled overhauls that are beyond the capacity of the ship's force to accomplish. This element is the sum of subelements 303.2.1 and 303.2.2.

303.2.1 Labor: The cost of the labor expended by the shipyard or other industrial facility in support of ship serviced. The labor cost will be a fully-loaded cost to account for a pro rata share of direct, indirect, and overhead costs.

303.2.2 Material: The cost of the material and repair parts expended by the shipyard, or other industrial facility, in support of ships serviced.

303.3 Fleet Modernization Program: The cost of the installation of alterations and improvements to effect changes in a ship's configuration or equipment to improve its safety, habitability, maintainability, or technical characteristics. (Changes, modifications, alterations, or other improvements designed to enhance the performance, or improve or alter the mission capability of the ship are excluded. The categories covered by this exclusion are investment in the system and therefore will be included in the System Investment element 201.3. If it

is not feasible to distinguish among modifications, then all modifications may be included in the O&S elements 303.3 and 307.2.) This is primarily a labor cost, although common miscellaneous industrial material (such as wire, cable, piping, fitting, sheet metal, locally procured or fabricated items, etc.) may be provided by the installation activity. The labor cost will be a fully-loaded cost to account for a pro rata share of direct, indirect, and overhead costs. Special material required for these alterations or modifications is covered in element 307.2.

303.4 Selected Restricted Availability (SRA): The cost of shipyard periods scheduled in advance for the accomplishment of maintenance. SRA schedules and duration shall be specified. This element is the sum of sub-elements 303.4.1 and 303.4.2.

303.4.1 Labor: The cost of the labor expended by the shipyard in support of ships serviced. The labor cost will be a fully-loaded cost to account for a pro rata share of direct, indirect, and overhead costs.

303.4.2 Material: The cost of the material and repair parts expended by the shipyard in support of ships serviced. (Replenishment parts which are covered in 307.1 are excluded.)

303.5 Repairable Component Repair: the cost of the repair, calibration and testing of the ship's equipment and components at industrial facilities. Missiles and other ordnance, ordnance equipment and components, and electronic, hull, mechanical, and electrical equipment and components designated for repair at industrial facilities are included. Each facility is to be accounted for separately. This element is the sum of subelements 303.5.1 and 303.5.2

303.5.1 Labor: The cost of the labor expended on repairable components. The labor cost will be a fully-loaded cost to discount for a pro rata share of direct, indirect, and overhead costs.

303.5.2 Material: The cost of the material and repair parts expended on repairable components.
(Replenishment spares, which are covered in 307.1 are excluded.)

304 DEPOT SUPPLY: The cost of procuring, receiving, storing, issuing, managing, and controlling the inventories of materials (i.e., wholesale supply functions) needed for the ship's operation and maintenance; and the cost of providing engineering and technical services, technical documentation, and logistics information system support. This element is the sum of subelements 304.1 and 304.2.

- 304.1 General Support: The cost of supply and information functions that support the ships, but the costs for which are not easily allocable and/or are small in relation to the total. Such functions as the operation of Inventory Control Points (ICPs), Supply Depots, other field support, technical documentation update, etc., are included.
- 304.2 Engineering and Technical Services: The cost of engineering and technical support services other than those supplied by IMAs and depot maintenance activities.
- 305 SECOND DESTINATION TRANSPORTATION: The cost of Transportation of material for the ships subsequent to its initial receipt by the Mobile Logistic Support Force, which are accounted for in 312.1. Transportation of repairable items is included.
- 306 PERSONNEL SUPPORT AND TRAINING: The cost of individual training (initial and replacement), health care, permanent change of station (PCS), and other personnel support. This element is the sum of subelements 306.1 through 306.4.
- 306.1 Individual Training: The cost of recruit, specialized, and professional training, including the basic pay and allowances for instructors and for personnel in training. The cost of pay and allowances for personnel attached to the ship is included in element 301.1. This element is the sum of 306.1.1 and 306.1.2.

306.1.1 Special Training: These costs cover that personnel in training uniquely related to the characteristics of the ship.

306.1.2 General Training: These costs cover all personnel training except that uniquely related to the characteristics of the ship.

306.2 Health Care: The cost of providing ashore medical support to personnel attached to the ship. Organizational medical support which is accounted for in element 301, is excluded.

306.3 Personnel Activities: The permanent change of station (PCS) to move personnel assigned to staff or support positions for the ship. The cost of these moves includes a proportionate share of personnel pipeline PCS costs of moves for accessions, separations, rotations, operations, and training.

306.4 Personnel Support: The costs to operate training facilities and medical facilities. These costs include supplies, services, and material; travel expenses; and other variable personnel-oriented support costs incurred at training facilities and medical facilities.

307 SUSTAINING INVESTMENTS: The cost of direct investment support to the ship, such as replenishment spares, special program material, and training expendable stores. This element is the sum of subelements 307.1, 307.2, and 307.3.

307.1 Replenishment Spares: The cost of the recurring procurement of spares to replenish rotatable pools of repairable components depleted through abandonment, loss, or survey. Spares are recoverable components, subassemblies, assemblies, equipments, or end items installed or otherwise placed in use while replaced items are undergoing maintenance, repair, overhaul, or salvage at other than the organizational level. The acquisition of initial spares, covered in 205.5 is excluded.

307.2 Special Program Material: The cost of the acquisition of special material for alterations or modifications needed for effecting improvements in the ship's safety, habitability, maintainability, or technical characteristics. (Changes, modifications, alterations, or other improvements designed to enhance the performance, or improve or alter the mission capability of the ship are excluded. The categories covered by this exclusion are investments in the system and therefore will be included in the System Investment element 201.3. If it is not feasible to distinguish among modifications, then all modifications may be included in the O&S elements 303.3 and 307.2.) Miscellaneous material and installation labor are counted under element 303.3.

307.3 Training Expendable Stores: The cost of the expendable ordnance, ammunition, pyrotechniques, missiles, ballistic weapons, guided weapons, torpedos, mines, depth charges, sonobuoys, etc., used by the ship in training exercises.

DEFINITIONS FOR THE COLLATERAL COST ELEMENTS STRUCTURE (CES)

The definitions presented here illustrate those cost elements that may be considered as variable in the context of a particular program. The cost elements have been assigned numbers for ease of identification, reference, and discussion. The numbering scheme is identical to that used in the presentation of the basic CES above.

COLLATERAL COST ELEMENT DEFINITIONS FOR SHIPS

400 ASSOCIATED SYSTEMS: The sum of cost elements 401 and 402.

401 SUPPORT INVESTMENT: The sum of cost elements 401.1, 401.2, and 401.3.

401.1 Mobile Logistic Support Force: The cost of constructing, converting, altering, or modifying oilers, ammunition ships, supply ships, etc., to support the operation of these particular ships.

401.2 Tenders and Repair Ships: The cost of constructing, converting, altering, or modifying tenders and repair ships for the intermediate maintenance of these particular ships.

401.3 Ashore IMA: The cost of constructing, converting, altering, or modifying ashore facilities to provide intermediate maintenance for these particular ships. Investments made solely for repairable component repair facilities, which should be reflected in 205.4.1, are excluded.

402 OPERATING AND SUPPORT: The sum of cost elements 402.1 through 402.4.

402.1 Mobile Logistic Support Force (MLSF): The significant incremental costs of operating and supporting the MLSF (except tenders and repair ships) that result from the introduction and operation of these particular ships. The O&S cost of the MLSF ship is to include the cost categories in the 300 series defined by this appendix. Each MLSF ship type is to be accounted for separately.

402.2 Tenders and Repair Ships: The significant incremental costs of operating and supporting the tenders and repair ships that result from the introduction and operation of these particular ships. The O&S cost of the tenders and repair ships is to include the cost categories, (except for direct labor, covered in 302.1.1) in the 300 series defined by this appendix. If these particular ships require particular tenders or repair ships, the cost associated with them must be shown separately.

402.3 Ashore IMA: The significant incremental costs of operating and supporting the ashore IMAs that result from the introduction and operation of these particular ships. The O&S cost of the shore IMAs include manpower, (except for direct labor, covered in 302.2.1), training, personnel support, and other support as defined by the 300 series of this appendix. These costs also include support services received from host facilities. If these particular ships require particular IMAs, the cost associated with them must be shown separately.

402.4 Embarked System: Pro rata share of the operation and support costs of embarked systems, such as helicopters, etc., not intended to be permanently affixed to the ship. Costs will be shown separately for each kind of "embarked system". The embarked systems will be specifically identified.

APPENDIX B

BASIC OUTLINE OF A SYSTEM PROGRAM DEFINITION

STATEMENT FOR SHIPS [Ref. 30]

A. MISSION PROFILE

1. Warfare
2. Mobility
3. Command and Control
4. Fleet Support Operations
5. Noncombatant Operations
6. Other Inherent Capabilities

B. SHIP CHARACTERISTICS

1. Physical Description (Platform)
 - a. Length
 - b. Beam
 - c. Draft
 - d. Displacement (full load and light ship)
2. Physical Description (Subsystems)
 - a. Propulsion
 - (1) Type and Number of Shafts
 - (2) Speed and Endurance
 - Maximum (knots, nautical miles)
 - Cruise (knots, nautical miles)
 - Economical (knots, nautical miles)

b. Electrical

- (1) Type, number and capacity of ship's service and emergency generators
- (2) Condition I and III electrical loads

c. Auxiliary

- (1) Type, number and capacity of significant components (e.g., air conditioning, fire pumps, etc.)

d. Armament

- (1) Anti-Submarine Warfare Systems
- (2) Anti-Ship Missile Defense Systems
- (3) Anti-Surface Warfare Systems
- (4) Anti-Air Warfare Systems
- (5) Associate Sensors
- (6) Unreplenished Endurance (expendable stores capacity, by type)

e. Command and Surveillance

- (1) Command and Control
- (2) Navigation
- (3) Interior Communications
- (4) Exterior Communications
- (5) Surveillance (surface)
- (6) Surveillance (underwater)
- (7) Countermeasures
- (8) Fire Control

f. Air Systems

- (1) Aircraft Capacity (number and type)
- (2) Flying hours per month

- (3) Air Control Capabilities
 - (4) All Weather Handling Capability
 - (5) Aviation Fuel Capacity (flight hours)
 - (6) Unreplenished Aviation Stores Endurance (expendable stores, by type)
 - (7) Maintenance Support (organizational or IMA)
- g. Mobile Logistic Support Force (MLSF)
 - (1) Carrying Capacity (by commodity)
 - (2) Transfer Rate (by commodity)
 - (3) Number of Replenishment Stations (by type)
- h. Amphibious Systems
 - (1) Troop Capacity
 - (2) Vehicular Capacity
 - (3) Cargo Capacity
 - (4) Helicopter Spots
 - (5) Ship-to-Shore Movement Systems
- i. Support Systems
 - (Specialized capabilities for towing, salvage, and repair)
- 3. Design Characteristics
 - a. Habitability (square meter per person)
 - b. Hardening
 - (1) Shock
 - (2) Airblast
 - (3) Nuclear, Biological, Chemical Warfare
 - c. Damage Control Provisions (e.g., separation of vital system, compartmentation, etc.)

d. Radiated Noise Characteristics

(1) Cavitation Speed

e. Margins for Growth

(1) Accommodations (percent of complement)

(2) Future Combat System (space, weight, moment)

(3) Electrical (Kw)

(4) Capabilities and Constraints for Future Aircraft
(e.g., hangar size, deck loading, etc.)

4. Expected Operational Life

a. Platform

b. Major Subsystems

5. Crew Requirements

a. Officers

b. Sub-Officers

c. Sailors

C. ACQUISITION PROGRAM

1. Design-to-Cost Goal

2. Number of Ships

3. Production/Utilization Schedule

4. Contract Commitments on Support Cost Control

5. Government Furnished Equipment Policy

6. Standardization Provisions

D. DEPLOYMENT

1. Peacetime

a. Basing and Deployment Plan

- b. Speed-Time Profile
 - c. Maintenance and Overhaul Cycle
 - 2. Contingency/Wartime
 - a. Basing and Deployment Plan
 - b. Speed-Time Profile
 - c. Maintenance and Overhaul Cycle
- E. SUPPORT CONCEPT
 - 1. Initial Support Plan
 - a. Peacetime
 - b. Contingency/Wartime
 - 2. Sustaining Support Plan
 - a. Peacetime
 - b. Contingency/Wartime
- F. LOGISTIC GOALS
 - 1. Weapon System Availability
 - (By mission area)
 - 2. Subsystem Availability
 - (By mission area)

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